CRYSTALLINE GUIDANCE MODULE

A Systemic Risk Mitigation Architecture for the Geostationary Satellite Fleet

Kase Branham • March 2026 • **Full technical brief and radiation physics argument available under NDA**

THE PROBLEM

Every satellite in the geostationary arc shares the same systemic vulnerability: CMOS-based processors that fail through identical physical mechanisms.

A high-altitude EMP or severe solar particle event doesn't destroy one satellite — it triggers simultaneous total-loss claims across the portfolio.

Conventional redundancy installs a second processor exposed to the same threat. It addresses random failure. It does not address correlated failure.

Insurance exposure: $300–500M per asset, $20–30B fleet-wide, single failure mode.

THE GAP

CMOS processors fail in correlated events through four well-understood mechanisms: total ionizing dose, single-event upset, single-event latchup, and gate oxide rupture.

No commercially available safe-mode controller uses a computational state variable that is decoupled from these failure paths.

You cannot close this gap by improving electronic design. You can only close it by using a different physical mechanism entirely.

The gap is categorical. It cannot be matched by further hardening of existing technology.

THE ARCHITECTURE

CGM implements the complete satellite safe-mode function set using mechanical wave propagation logic — a physical category with no charge storage nodes, no PN junctions, no gate oxides, and no single-event latchup paths.

Logic is physically pre-encoded at fabrication. Deterministic. Not field-reprogrammable. Fixed-function by design — the same property that makes core rope memory in the Apollo Guidance Computer the most reliable component on the vehicle.

The "program" is geometry. It cannot be erased by the events that destroy conventional electronics.

System Architecture

PRIMARY FLIGHT COMPUTER

Normal operations — full mission capability

↓ *Correlated failure event* ↓

High-altitude EMP / severe solar particle event

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Dissimilar backup — mechanically encoded logic, no CMOS failure paths

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ACTUATOR CONTROL

Reaction wheels / thrusters / heaters — simple hardened drivers only

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SATELLITE SURVIVES IN SAFE MODE

Asset controllable — orbital slot preserved — partial loss, not total loss

Failure Scenario: Severe Solar Particle Event

	WITHOUT CGM	WITH CGM	INSURANCE OUTCOME
	1. Solar particle event causes primary bus latchup	1. Solar particle event causes primary bus latchup	**Without CGM:** $300–500M total

	2. Backup processor experiences identical latchup 3. Satellite enters uncontrolled attitude drift 4. Solar arrays lose sun-pointing — power fails 5. Propellant freezes, batteries discharge 6. Ground loses all contact **7. Orbital slot forfeited — total loss declared**	2. CGM detects loss of primary — assumes control 3. Attitude restored to sun-pointing via CGM threshold logic 4. Power maintained — survival heaters activated 5. Telemetry beacon active — ground maintains contact 6. Station-keeping maintained within slot tolerance **7. Recovery operations begin — orbital slot preserved**	loss claim Orbital slot forfeited **With CGM:** $50–100M degraded mission claim, or zero if recovered **Avoided loss: $200–400M per event**

Why CGM Does Not Share CMOS Failure Modes

HOW CMOS FAILS IN SPACE	WHY CGM DOES NOT SHARE THESE PATHS
Total Ionizing Dose (TID) Charge accumulates in gate oxides over time, shifting threshold voltages until transistors fail to switch correctly.	**No charge storage nodes** Computational state is mechanical displacement and wave phase, not stored charge. There is no accumulated charge to shift or corrupt.
Single-Event Upset (SEU) A single ionizing particle deposits charge in a memory cell or logic node, flipping a stored bit. Software state is corrupted.	**No PN junctions** No semiconductor junctions means no latchup path. The parasitic thyristor mechanism that kills CMOS under SEL does not exist in this architecture.
Single-Event Latchup (SEL) A particle triggers a parasitic thyristor path in CMOS structure, creating a low-resistance short-circuit. Device draws destructive current until power is removed — or permanently fails.	**No gate oxides** There are no oxide layers to accumulate TID damage or to rupture under transient voltage stress.
Gate Oxide Rupture High-energy particles or EMP transients puncture gate oxide layers. Permanent failure. Not recoverable.	**No upset-sensitive memory states** Logic is encoded in fabricated geometry, not in stored bit states. A particle strike cannot flip the program. The geometry is the program.

The Insurance Arithmetic

Market exposure	Premium incentive structure
• $300–500M manufacturing + launch cost per GEO satellite • Orbital slot value independent of satellite — sometimes exceeds it • $20–30B total insured GEO fleet; annual premiums ~$700M–1B • Single correlated event affecting five satellites: $1–2B simultaneous claims	• 5–15% annual premium discount on a $3–5M premium = $2.25–11.25M over 15-year mission • Cumulative discount can exceed total module cost — negative net cost to operator • Insurer co-developing the discount framework has direct actuarial incentive: avoided claims exceed premium

Module economics

- Module cost at initial production: $5–10M per unit
- Integration cost per satellite: $1–3M
- Total installed cost: $6–13M — approximately 1.5–4% of insured asset value
- One avoided total loss pays for a twenty-satellite fleet installation

reduction

Development path

- Phase 1 — Lab demonstrator (Yrs 1–3): ~$3–5M
- Phase 2 — Space qualification (Yrs 3–5): ~$15–30M
- Phase 3 — Hosted flight demonstration (Yrs 5–7): ~$20–40M
- Phase 4 — Fleet deployment + premium structures (Yrs 7–10)

Partnership Paths

Technical Partners

University materials science and phononics research groups, national laboratories (Sandia, JPL, NIST) capable of executing the Phase 1 laboratory demonstrator.

Seeking: lab capability + co-investigator interest + SBIR pathway

Aerospace Primes

Satellite bus manufacturers and systems integrators evaluating next-generation survivability options for GEO platforms.

Seeking: integration roadmap discussion + licensing framework

Space Insurers

Lloyd's syndicates, Marsh, Aon, AXA XL Space — underwriters modeling correlated GEO exposure who have direct financial incentive to co-develop actuarial validation and premium discount structures.

Seeking: actuarial co-development — avoided claims exceed premium reduction

Contact: Kase Branham -Kase1111@gmail.com